SPECIFICATIONS FOR A MULTIPLE-MODE SCANNING PROBE MICROSCOPE SYSTEM FOR THE NAVAL RESEARCH LABORATORY

A. STATEMENT OF PURPOSE

The Naval Research Laboratory (NRL) requires a new state-of-the-art multi-mode scanning probe microscope system for a continuing research effort in nanometer-scale lithography and pattern formation by direct proximal-probe-induced surface modification of semiconductor and metal surfaces. The new system must be capable of:

1. characterizing a wide variety of surfaces by various scanning probe microscope techniques;
2. modifying surfaces directly at the nanometer scale;
3. detecting and characterizing the modifications by subsequent imaging.

The minimum requirements and technical specifications are detailed below. Prospective vendors are required to provide a detailed system description (including drawings/pictures where appropriate) and a single price quotation for all the required items (Sections B through F inclusive, below). Prospective vendors are also invited to provide additional bids (prices itemized for each item) for any or all of the optional items listed in Section G. Conditions of shipment, delivery, and acceptance are outlined in Section H. Minimum vendor qualifications are described in Section I.

B. MEASUREMENT TECHNIQUES REQUIRED

The SPM system must include the following imaging techniques, for which the terms used to describe each technique are understood to have the meanings commonly understood in the field, unless specifically defined:

1. Scanning Tunneling Microscopy (STM).
2. Atomic Force Microscopy (AFM), including contact mode, non-contact mode, and intermittent-contact / tapping mode.
3. Lateral Force Microscopy (LFM).
4. Force Modulation Microscopy (FMM).
5. Electrostatic Force Microscopy (EFM).
6. Scanning Capacitance Microscopy (SCM).
7. Magnetic Force Microscopy (MFM).
8. Scanning Thermal Imaging Microscopy (SThIM), defined here as a method of imaging variations in sample surface temperature.
9. Phase Detection / Imaging Microscopy (PDIM), defined here as a method of mapping the phase shift of the probe oscillation in intermittent contact / tapping mode.

C. ADDITIONAL TASKS

In addition to the above techniques of imaging, the system must be able to perform the following tasks with each of the listed techniques:

1. Phase Sensitive Detection (PSD): Detection of the phase lag between the driving signal and the detected probe response, performed simultaneously with at least one AFM mode (contact, non-contact, or intermittent contact modes) and each of the following modes: EFM, FMM, and MFM.
2. Force vs. Distance curves for AFM.
3. Surface Modification / Nanolithography (described in detail in Section E below).

D. SYSTEM SPECIFICATIONS

The required instrument must meet or exceed the following speicifications:

1. SAMPLE STAGE must:
   - hold samples up to 50 mm in diameter with scanned tip access to entire sample;
   - handle samples up to 12 mm in thickness.

2. OPTICAL MICROSCOPE must:
   - have on-axis view of both cantilever and sample;
   - be capable of 1.5 micrometer resolution or smaller at maximum magnification;
   - have a field of 400 x 400 micrometers or larger at minimum magnification;
   - must be able to zoom continuously between minimum and maximum magnifications, with possible allowance for change of objective lenses by manual rotation of lens platen if necessary;
   - have color CCD camera with at least 13" color monitor.

3. SYSTEM CONTROLLER must:
   - have at least 3 independent digital-to-analog converters (DACs), each with at least 16 bit precision, one for each of the three piezotransducers (x,y,z);
   - have minimum lateral resolution of 0.1 nanometer (nm) or smaller;
   - have minimum vertical resolution of 0.1 nm or smaller;
   - have noise level of 0.05 nm or smaller;
   - have completely digital control electronics and digital processing;
   - allow up to at least 512x512 data points per image (up to 90 micrometer scan size);
   - allow up to 5 selectable channels of simultaneous data capture.

4. POSITION CONTROL SYSTEM must:
   - have closed-loop piezo control system with 2% accuracy or better over full scan range, and 1% accuracy or better over the center third of the full scan range;
   - correct for piezo non-linearities in x and y scans to within 2 nanometers.

5. CONTROL COMPUTER must come fully operational and have at least:
   - 400 MHz Pentium II processor or equivalent;
   - 64 MB RAM;
   - 19" (diagonal) color monitor;
   - 24x CD ROM drive;
   - 8 GB hard drive (with SCSI interface);
   - 3.5" 1.4 MB floppy drive;
   - Microsoft Windows 95 or later version and all other software installed;
   - keyboard, mouse, and pad;
   - two PCI bus slots available.

6. TIP-HOLDER & SCANNER SYSTEMS must:
   - have at least 90 micrometer scan range in each of x and y (horizontal) directions;
   - have at least 6 micrometer scanning range in z (vertical) direction;
   - accommodate a wide variety of cantilever tips from various manufacturers;
   - support all scanning modes listed above in B (REQUIRED TECHNIQUES) and
   - C (ADDITIONAL TASKS) above.

7. SIGNAL ACCESS MODULE must provide an open access to all (at least 30) input and output channels.

8. COMPUTER SOFTWARE must:
   - be completely compatible with Microsoft Windows 95 or later version;
   - allow simultaneous data collection, image processing, and use of Windows-compatible programs;
   - be usable with Windows-compatible printers and networks;
   - be able to export data to Excel, Word, PowerPoint, and other Windows programs;
   - have automatic tip approach for all imaging modes listed in Section B above;
   - allow simultaneous single-screen display of SPM system controls, real-time display of up to 3 simultaneous data channels, and real-time display of individual line trace;
   - allow partial image processing and 3-D image rendering with fully rotatable view of image;
   - have user-selectable flattening and filtering algorithms;
   - allow real-time line measurements during imaging;
   - allow quantitative line, area, and volume measurements;
   - allow software-selectable inclusion/exclusion areas for flattening and area analysis;
   - allow user-settable averaging box for trench and zone measurements;
   - allow real-time display of all system voltages;
   - allow graphical display of selected detector outputs;
   - allow image-processing memory to re-apply processing parameters to multiple scans/samples;
   - support interlaced / interleaved scanning and sine scan / rounded scan mode;
   - support all modes and capabilities described in sections B and C above.

9. CANTILEVERS INCLUDED:

The system must include at least 10 cantilevers for each imaging mode requiring a separate type of cantilever, including a variety of standard cantilevers used in general purpose (both contact and noncontact) AFM modes, defined here to include cantilevers with microtips (nominal tip radius ~ 20-60 nm), sharpened microtips (nominal tip radius ~ 10-40 nm), and ultrasharp tips (radius < 10 nm).

E. SURFACE MODIFICATION & NANOLITHOGRAPHY REQUIREMENTS

In addition to high resolution imaging of a wide variety of surfaces at the nanometer and atomic scale, the system will be used in a state-of-the-art research program to investigate the uses of proximal probes to modify surfaces at the nanometer-scale (and in some cases at the molecular and atomic scale), and to use these surface modifications to fabricate nanometer-scale structures and devices. The system must therefore have a nanolithography pattern generation capability, including all hardware and software to generate a pattern of arbitrary shape and complexity, of arbitrary dimensions specified by the operator up to the maximum scanning limits of the piezoscanners. The maximum write speed should be at least 200 micrometers per second. The patterns must be able to be defined by operator choice from the following capabilities:

1. Point lithography, defined here as specifying the position of a point in the plane to which the tip traverses and then writes the point using a technique chosen by the operator from among any of the writing techniques defined below.

2. Vector lithography, defined here as specifying the location of two points in the plane, in which the tip traverses to the first point, turns on the writing technique chosen by the operator from the list below, traverses at a speed chosen by the operator to the second point, and then turns off the writing technique upon reaching the second point.

3. Bitmap lithography, in which a pattern of arbitrary complexity formed by multiple points, each at a location in the scan field specified by the operator by his choice of mouse or by keypad, is written by any one of the techniques below chosen by the operator, by the tip raster-scanning the field and writing each point in succession as it reaches it, thus forming the chosen pattern.

The patterns defined by the software described above must be able to be made on a surface of a material of arbitrarily chosen composition consistent with the method chosen (e.g., conducting substrate for STM or other modes of pattern generation requiring substrate conductivity) by any method chosen by the operator from among the following:

1. Nanoindentation with AFM tip.

2. Internally generated and controlled voltage pulse (starting and ending bias chosen anywhere in range from –10 to +10 volts, minimum) with maximum pulse duration of at least 1 second duration and minimum duration no greater than 1 millisecond.

3. TTL trigger pulse (rise and fall times each less than one millisecond) internally generated and controlled by lithography software to turn on and off the output of an external voltage source such as a Keithley Model 230 Programmable Voltage Source and /or an external current source such as a Keithley Model 224 Programmable Current Source (external voltage and current sources source not included; see Options below).

F. ON-SITE INSTALLATION AND INSTRUCTION

Complete installation and training of at least two operators at customer site.

G. OPTIONS

Vendors are invited to provide individual prices for any, each, or all of the following optional items 1 – 21 if they are not already included in the system as configured for the required specifications above. NRL reserves the right to purchase some, all, or none of the optional items. Choice of winning bidder will be made solely on the basis of lowest price from among those bidders meeting all the specifications to the required items of Sections B through F inclusive. However, a decision to purchase any of the optional items will be made on these individual options meeting the needs of the NRL research agenda (as determined solely by NRL), and by the performance specifications and the price of each option.

1. Pulsed Force Microscopy.

2. Electrochemical Microscopy.

3. Conductive AFM, defined here as a mode which images the electrical conductivity of a sample's surface with an electrically conducting AFM tip.

4. Tunneling AFM, defined here as a method of characterizing thin insulating films using Fowler-Nordheim tunneling.

5. Scanning spreading Resistance Microscopy, defined here as a method of using scanned spreading resistance measurements to generate a two-dimensional image of dopant profiles in semiconductor layers.

6. Chemical Force Microscopy.

7. Chemically active or chemically functional AFM tips, defined here as any tips for any mode of SPM that that are chemically active and can detect and/or change the chemical functionality of a surface being scanned.

8. Current Imaging Tunneling Spectroscopy, defined here as generating an image from a series if IV plots, each taken from a separate point in a grid.

9. Vibration damping pad.

10. Vibration isolation table.

12. Acoustic isolation system.

13. Liquid cell for AFM modes.

14. Additional general-purpose cantilevers; any or all of the following:
    a.) approximately 300 unmounted noncontact-mode ultrasharp levers;
    b.) approximately 300 unmounted au-coated microlevers and/or sharpened microlevers and/or ultrasharp levers;
    c.) approximately 250 unmounted Au-coated sharpened microlevers and/or sharpened microlevers and/or ultrasharp levers;
    d.) any other general purpose cantilevers the vendor wishes to offer in large lots;

15. Additional Specialized Cantilevers; any or all of the following:
    a.) small lot (approximately 5 to 20) contact unmounted diamond-coated ultrasharp levers;
    b.) small lot (approximately 5 to 20) Scanning Capacitance Microscopy cantilevers;
    c.) small lot (approximately 5 to 20) Magnetic Force Microscopy cantilevers;
    d.) small lot (approximately 5 to 20) Scanning Thermal Imaging Microscopy cantilevers;
    e.) small lot (approximately 5 to 20) carbon nanotube tipped cantilevers;
    f.) any other specialized cantilevers the vendor wishes to offer in small lots.

16. External voltage source compatible with this system such as a Keithley Model 230 Programmable Voltage Source to be used as described in Section E above.

17. External current source compatible with this system such as the Keithley Model 224 Programmable Current Source to be used as described in section E above.

18. External multi-function electrometer compatible with this system such as the Keithley Model 617 Programmable Electrometer to be used in conjunction with the voltage and current sources described immediately above.

19. Any optional upgrades to the optical microscope.

20. Any optional upgrades to the computer system, including but not limited to any or all of the following:
    a.) color printer;
    b.) 100 MB or larger zip drive;
    c.) video capture card;
    d.) ethernet adapter;
    f.) any additional upgrades to computer hardware of software not otherwise included.

21. Any additional upgrades that the vendor wishes to suggest or recommend. The vendor should provide reasons for or benefits from any suggested options.

H. CONDITIONS OF SHIPMENT, DELIVERY, AND ACCEPTANCE

The price of shipment of the entire system to NRL must be included in the offered price. The system must be delivered to NRL, installed, and have demonstrated that it meets all specifications. Acceptance will be 7 days after equipment is installed.

I. VENDOR QUALIFICATIONS

Vendor must offer an "off-the-shelf" system, not a new or prototype design. The vendor must have an established reputation for providing reliable, high-quality multi-mode SPM systems of the type described in the specifications. Specifically, the vendor must have an established customer base with at least 25 systems substantially similar to the one proposed here and meeting the specifications provided herein. The vendor must provide a user list for at least 5 similar systems they have sold and a point of contact for each.